Heavy Metal Loading in Agricultural Soils; Contribution of Tobacco Wastes. A Case Study of Morogoro Municipality, Tanzania

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Abstract: ***The concentration of heavy metals (Cu, Zn, Fe, Mn and Pb) in soil and tobacco wastes from Mwele and Kichangani in Morogoro Municipality were analyzed using X-Ray Fluorescent (XRF) technique. The mean levels in the soil in mg/kg dry mass at 'Mwele garden were Cu(54.62), Zn(119.37), Fe(49211.93), Mn(989.89) and Pb(14.41), that of Kichangani were Cu(13.39), Zn(15.12), Fe(7657.11), Mn(154.65) and Pb(6.20), that of tobacco wastes piles were Cu(11.30), Zn(27.33), Fe(2272.10), Mn(280.02) and Pb(0.69). The concentrations at the three sites displayed a similar trend; Fe >Mn > Zn >Cu >Pb while among the sites levels were in the trend Mwele > Kichangani >tobacco waste piles. The higher levels of residues at Mwele compared to Kichangani suggested significant contribution from the wastes piles. The higher residue levels at Mwele garden than at the piles suggested the high accumulation over years at Mwele gardens. The levels were within the permissible levels (TBS) but suggesting a long term environmental pollution risk due to continuing piling up of the residues. The study suggested thorough study of the routes of metal cycling on the area and hence carry out environmental impact and risk assessment.***

Keywords: Heavy metals, tobacco waste pile, environmental pollution, nutrient mobility, permissible levels, environmental impact and risk assessment, TBS

1. Introduction

Heavy metals exist naturally in the soil from the soil forming processes of disintegration of parent resources at rare levels (<1000 mg kg−1) and infrequently poisonous (Kabata-Pendias and Pendias, 2001; Pierzynski et al., 2000). Other heavy metals come from anthropogenic activities related to industry, agriculture, burning of fossil fuels, vehicular emission, mining and metallurgical processes and their waste disposal and are more moveable in the soil, hereafter biologically available than soil forming phenomena. The concentrations of heavy metals in soils are associated with biological and geochemical cycles and are influenced by anthropogenic activities, such as agricultural practices, transport, industrial activities and waste disposal. These elements, at concentrations exceeding the physiological demand of the plants, not only could administer toxic effect in them but also could enter food chains, get biomagnified and pose a potential threat to human health (Khan and Ghouri, 2011). Tobacco leaves (*Nicotiana tabacum*) can easily accumulate certain heavy metals in leaves (Konstansa *et al.,* 2012). Varying levels of heavy metals like cadmium (Cd), Lead (Pb) and Arsenic (As) in tobacco leaves have been reported (Konstansa *et al.,* 2012). Heavy metals can accumulate in the soils to toxic levels as a result of long term application of untreated waste and fertilizers. Some of the metals such as iron, manganese, zinc and copper are essential micronutrients and they are also very important for plant growth and yield. The high levels of metals in the soil indicate accumulations beyond which the plants can take.

At Mwele area, small scale farmers utilize tobacco wastes as a source of nutrients and as a pesticide for vegetable cultivation for a long time. Mwele gardens are located near the tobacco industry from which the tobacco wastes are piled outside and utilised for nutrient addition in the gardens. The study aims at assessing the tobacco wastes as one of the potential route of loading heavy metals in the soil. The study focused on the concentration levels of six toxic heavy metals (Cu, Zn, Fe, Mn, Pb and Cd) at Mwele and Kichangani areas as well as from the tobacco pile at Mwele to establish the contribution of the tobacco wastes in the pile to metal loading in the soils.

2. Materials and Methods

2.1 Study Area

The study was carried out at Mwele and Kichangani areas in Morogoro municipality in Tanzania (about 500m apart). Mwele site is located at about 2.2km from Msamvu-Bus station and on the east side there is Morogoro River which is used for irrigation of the gardens. In the upstream there are Mwele garden and the tobacco waste pile while far down stream there is Kichangani. The farmers at Mwele have been using the pile wastes at Mwele gardens as a source of the nutrients (Figure 1). The main activities conducted along these areas, is small scale cultivation of vegetables such as cowpeas (*Vigna unguiculata*), spinach (*Spinacia oleracea*) and *amaranthus*.The tobacco wastes from the pile have for long been used at Mwele gardens but not at Kichangani.

Figure 1: Study areas location as shown in GPS map

2.2 Sampling

Plots of about half acres were selected randomly at Mwele (four plots) and Kichangani (two plots). The plots were subdivided into four subplots and each plot subdivided into three subplots from which duplicate composite samples were collected at a depth of 0-15cm excluding the organic matter layer. This made a total of 54 samples with addition of 6samples for blank analysis (blank samples). The composite samples were marked as M_1 to M_{19} and K_1 to K_8 for Mwele and Kichangani samples, respectively. At tobacco waste pile, ten (10) subsamples were collected randomly from pile and mixed thoroughly in a plastic bag then divided by quartering and discard the two parts which were in opposite side until finally remain with only about one kg of duplicate composite samples, H_1 and H_2.

Figure 2: Sample collection at the Tobacco waste pile, Mwele

Soil samples were air dried in a glass house (about 40^0C), crushed and sieved through 2mm sieve then stored in envelopes. The samples of tobacco wastes were placed in an envelope, dried in oven at about 65^0C for 72 hours then grinded to fine powder. 50g of fine grinded soil and/or tobacco waste powder samples were analysed using X-Ray Fluorescent (XRF) machine.

3. Results and Discussion

3.1 Levels of Metals at Mwele Tobacco Waste Pile

The mean levels of heavy metals at the two waste piles were Cu (11.30), Zn(27.33), Fe(2272.10), Mn(280.02), and Pb(0.69) in mg/kg dry weight. The trend was Fe>Mn>>Zn>Cu>>>Pb with the levels of iron (Fe) and manganese (Mn) relatively higher than the rest. Similar pattern of occurrence of metals were found in cigarette brands with almost the same trend; Zn > Ni > Cu > Co > Cd > Pb (Golia et al, 2009**).** Iron and manganese occur often together in nature thus resulting to common pollution in groundwater emanating from processes like weathering of iron and manganese bearing minerals and rocks, such as amphiboles, ferromagnesian micas, iron sulphides, magnetite, oxides, carbonates, and iron clay minerals. Iron and manganese often occur naturally in deeper wells where the groundwater may have little or no oxygen, and in areas where groundwater flows through soils rich in organic matter. Co, Cr, Fe, Mn, Ni and Zn in agricultural soils has been associated with parent rocks and corresponded to the first principal component called the lithogenic component (Micó et al, 2006).

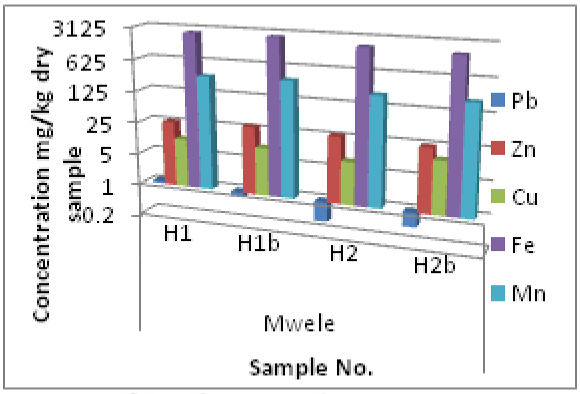

Figure 3: Mean Levels of Cu, Zn, Fe, Mn and Pb in Soil at the tobacco waste pile

High residues levels at the piles (Figure 3) may indicate high contamination levels in the tobacco fields from where the wastes emanated. A significant correlation was found between lithogenic metals and some soil properties such as soil organic matter, clay content, and carbonates, indicating an important interaction among them (Micó et al, 2006). The availability of high concentrations of metals in the tobacco wastes explains the high capacity of tobacco plants in removing the metals from the soil. Some of the metals such as iron, manganese, zinc and copper are important micronutrients and they are also very important for plant growth and yield (Zaprjanova, et al, 2006).

3.2 Levels of heavy metals at Mwele Gardens

The concentration at Mwele soil shows the same trend as the waste pile; Fe>Mn>>Zn>Cu>>>Pb (Figure 4). The mean levels in the soil in mg/kg at Mwele garden were Cu (54.62), Zn (119.37), Fe (49,211.93), Mn (989.89) and Pb (14.41). Generally the concentrations were higher than those at the piles and also at Kichangani.

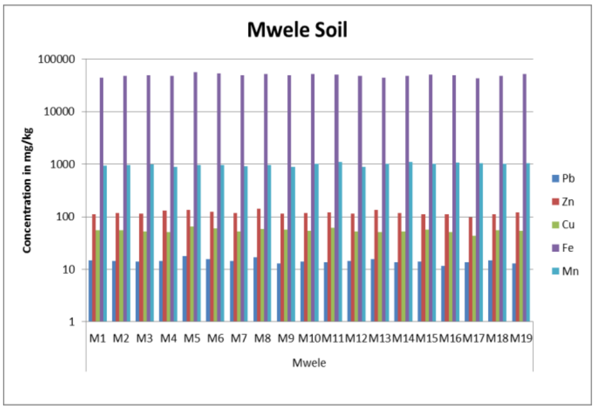

Figure 4: Levels of Cu, Zn, Mn and Pb in Soil at Mwele garden

These high levels at Mwele suggest piling up of the metals due to the use of tobacco wastes over years.

3.3 Levels of heavy metals at Kichangani Gardens

The concentration of heavy metals (Cu, Zn, Fe, Mn and Pb) in the soil at Kichangani gardens contained lower levels of residues than Mwele gardens but relatively higher than the piles.

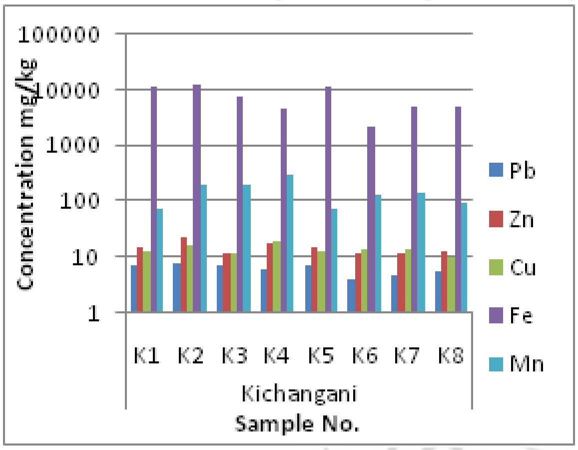

Figure 5: Levels of Cu, Zn, Mn and Pb in Soil from Kichangani vegetable garden

The mean levels at Kichangani were Cu (13.39), Zn(15.12), Fe(7657.11), Mn(154.65)and Pb(6.20). Levels at Kichangani reflected the mobility of the metals from the pile and Mwele gardens through natural ways rather than human transfer.

3.4 Variation of heavy metals in the three sites

The levels of heavy metals (Cu, Zn, Fe, Mn and Pb) in the soil at Mwele recorded with high concentration when compared to the levels in the soil from Kichangani. The results from tobacco wastes from the two piles at Mwele garden area contains heavy metals but in small amount compared to the concentration of the heavy metals in soil from Mwele and Kichangani vegetable gardens showing similar trend in all sites.

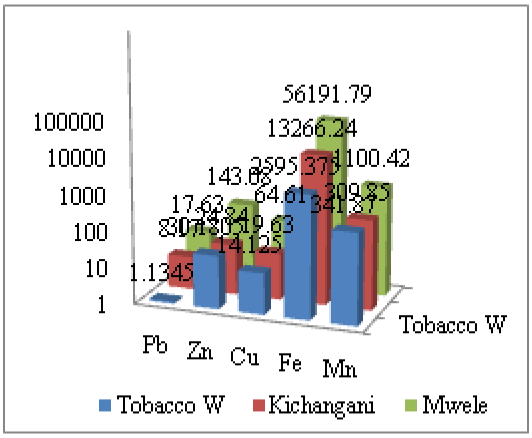

Figure 6: Variation of heavy metals in the three sites

The higher concentrations at Mwele than Kichangani indicated high contribution of the wastes from the piles. Apparently, the observed levels at Kichangani site require some further investigation. Kichangani area from the map (figure 1) is at the downstream of a river running from the hills through Mwele and piles locations. The two sites Mwele and piles on the upstream and very close together. The geographical location of Kichangani with respect to Mwele and the pile can support the occurrence of the metals at Kichangani as related to the tobacco pile. Estimation of other possible sources and loss routes of the metals were studied based on the physical properties of the metals. Some of the main routes include leaching, runoff soil formation, tobacco wastes and plant removal. Both total content and available fraction of these elements were detected in the upper 0-30cm layer. These contaminants seem to be resistant to leaching whereas runoff remained the main transfer route (Fodor & Szabo, 2004). Although heavy metals may also occur naturally from the soil forming processes like disintegration of parent resources at rare levels (Kabata and Pendias, 2001; Pierzynski et al., 2000), the argument is less supported in this study.

4. Conclusion

The study showed high contribution of the tobacco wastes in the loading and cycling of the metals on the area. The trend of the metals detected in the soil surface 0-15cm may explain the physic-chemical behaviour of the metals in the soil. Low levels of lead (Pb) relative to other metals explain the ease at which the metal can be eroded by runoff due to its low solubility to higher depths (Fodor & Szabo, 2004). However, runoff remained the major transfer route of the metals while the pile remained the main point source. The high levels of metals in the tobacco leaves (wastes) indicate the capacity of the tobacco in concentrating high amount of some metals in the leaves from the soil. This further suggests the possibility of employing tobacco plants for decontamination of areas containing too much of the metals unfit for agricultural activities (Baker et al, 1994).

5. Recommendations

This study recommends thorough monitoring of metals cycling in tobacco growing areas. The capacity of tobacco in taking up certain metals is important in two ways; to follow up the residues in tobacco after processing and assessing the possible risk to cigarette users. Likewise, the potential use of tobacco plants for decontamination of high residue contaminated lands.

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